EFFECTS OF DIFFERENT LIGHT INTENSITIES ON SURVIVAL AND GROWTH OF MARBLE GOBY LARVAE (*Oxyeleotris marmoratus*)

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ABSTRACT

Optimal threshold light intensity is crucial for normal larval growth and development especially for visual feeder. The present study is an attempt to determine the optimum and effects of different light intensity on survival and growth of marble goby, *Oxyeleotris marmoratus* in early larval stage. The newly hatched larvae with initial length 3.16±0.17mm were obtained from Fish hatchery, Universiti Malaysia Sabah. The treatments consist of 0, 500, 1000 and 2000 lux and tested in triplicates. Experiment duration was 15 days with stocking density was 15 individuals/L. By the end of the experiment, survival and growth in terms of final total length were observed. Results shown that treatment 1000 lux has significantly ($P<0.05$) higher survival (94.76±5.51%). While lowest survival was observed in treatment 0 lux (0.95±1.35%) and have no significant different ($P>0.05$) with treatment 500 (1.43±2.02%) and 2000 lux (25.71±17.61%). Meanwhile for the growth, 1000 lux shows relatively higher growth (5.33±0.06mm) but insignificantly ($P>0.05$) with treatment 500 lux (5.12±0.27mm). Whereas treatment 2000 lux shows significantly ($P<0.05$) lower growth (4.60±0.25mm) and no measurement could be done on treatment 0 lux as total mortality occur at the end of the experiment. For the feeding intake, it was observed that treatment 1000 lux shows relatively higher feed intake (11.33±0.94) compare to treatment 500 (6.33±4.49) and 2000 lux (7.66±5.43) at 15 d AH. In addition, larval condition especially on the retina development was also determined. It was observed that treatment 1000 lux shows a normal condition of retina with the well presence of cone cells. Whereas, treatment 0 and 2000 lux resulted in an abnormal condition of retina due to the damage of photoreceptors cells. Therefore, the optimum light intensity for marble goby larvae was 1000 lux. This study provides crucial knowledge to improve larval rearing technique for commercial purpose.

ABSTRAK

Keamatan cahaya ambang yang optimum adalah penting untuk pertumbuhan larva dan perkembangan yang normal terutama bagi pemakan yang menggunakan visual. Kajian ini adalah suatu percubaan untuk menentukan cahaya optimum dan kesan keamatan berbeza kepada kemandirian dan pertumbuhan ketutu, *Oxyeleotris marmoratus* di peringkat awal larva. Larva yang baru menetas dengan kepanjangan awal 3.16±0.17mm diperolehi dari pusat penetasan ikan, Universiti Malaysia Sabah (UMS). Rawatan yang terdiri daripada 0, 500, 1000 dan 2000 lux diuji di dalam tiga replikasi setiap satunya. Tempoh eksperimen adalah 15 hari dengan kapasiti 15 individu/L. Di akhir eksperimen, kemandirian hidup dan pertumbuhan dari segi jumlah panjang diperhatikan. Keputusan telah menunjukkan bahawa rawatan 1000 lux mempunyai perbezaan beerti ($P<0.05$) yang lebih tinggi dalam kemandirian hidup (94.76±5.51%). Manakala, rawatan 0 lux mempunyai kemandirian hidup yang rendah (0.95±1.35%) dan tiada perbezaan beerti ($P>0.05$) dengan rawatan 500 (1.43±2.02%) dan 2000 lux (25.71±17.61%). Sementara itu, bagi pertumbuhan, 1000 lux menunjukkan pertumbuhan yang lebih tinggi (5.33±0.06mm) tetapi tiada perbezaan beerti ($P>0.05$) dengan rawatan 500 lux (5.12±0.27mm). Manakala, rawatan 2000 lux menunjukkan perbezaan ketara ($P<0.05$) pertumbuhan yang lebih rendah (4.60±0.25mm) dan tiada pengukuran panjang boleh dilakukan pada rawatan 0 lux disebabkan oleh kematian yang tinggi di akhir eksperimen. Keadaan larva terutama sekali keadaan retina juga telah diperhatikan. Diperhatikan bahawa rawatan 500 dan 1000 lux menunjukkan perkembangan pembentukan retina yang baik dan normal. Manakala rawatan 0 dan 2000 lux menunjukkan kerosakan pembentukan retina yang tidak normal terutamanya pada sel-sel photoreceptors. Oleh itu, keamatan cahaya optimum untuk larva ketutu adalah 1000 lux. Kajian ini telah memberi pengetahuan penting untuk memperbaiki teknik penternakan larva untuk tujuan komersil.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

LIST OF SYMBOLS AND ABBREVIATIONS

<	Below
°C	Degree celcius
%	Percentage
BW	Body weight
d AF	Days after fertilization
d AH	Days after hatching
HCG	Human Chorionic Gonadotrophin
h AF	Hours after fertilization
H&E	Haematoxylin and Eosin
IU	International unit for weight
Kg	Kilogram
L	Litre
mL	Milliliter
mm	Millimeter
µm	Micrometer
ppt	Part per thousand
TL	Total length

LIST OF APPENDIXES

CHAPTER 1

INTRODUCTION

1.1 Aquaculture Status

Asia regions play an important role in aquaculture. In year 2004, Asia regions had the highest aquaculture production which was 92% of total global aquaculture production. Generally, fish has become an important export commodity globally in many countries. Increasing in the human population cause the demand in fish also increased, thus putting the pressure on aqua culturist to meet the demand. This is because of capture fishery only in the wild are not able to meet and fulfill the demand (Hihelgo, 2008). Therefore, in order to fulfill the demand, development of aquaculture has been seen as one of the solutions.

Malaysia is one of the countries that have a rapid development of aquaculture in Asia regions. Fishery sector in Malaysia has plays an important role of providing fish as a source of food and protein (Department of Fisheries Malaysia, 2000). In year 2000, aquaculture production in Malaysia had contributed about 1.6% to the National Gross Domestic Product (GDP). It also provided direct employment to 81,994 of fishermen and also 21,774 of fish culturist. At the meantime, aquaculture sector has contributed about 11.6% of total fish production which constituted about 167,894 tons of production. In addition, freshwater aquaculture production contributed 30.2% of total aquaculture production in Malaysia which 50,688 tons of production (Department of Fisheries Malaysia, 2000).

Through this aquaculture industry, many advantages can be offered to the farmers and researchers. Therefore, high interest was given especially on to culture the high value species as a target for the continuous of aquaculture sector. The demand for high value species either in marine or freshwater is keep on increasing as the Malaysian economy has improves and people's standard living also increased (Senoo *et al.*, 1997).

Since 1997, freshwater fishes has contributed the second highest of aquaculture production after the molluscs production. Major freshwater species cultured are carps, tilapia and catfishes (FAO, 2006). In order to enhance the production of aquaculture, it has led to the search of new species of promising candidates. Among the potential species, marble goby, *Oxyeleotris marmoratus* has been chosen and become one of the most attractive candidates for diversification of aquaculture (Senoo *et al.*, 1994a; Amornsakun *et al.*, 2002; Luong *et al.*, 2005).

1.2 Target species

The largest member of the Goby family is marble goby, *Oxyeleotris marmorata* (Smith, 1945). Marble goby (Photo 1.1) is also known as 'ikan ketutu' or 'ikan hantu' and 'soon hock' in malay and chinese respectively and it is also commonly known as 'sand goby' (Senoo *et al.*, 1994a). Marble goby is a carnivorous fish that can be found in Southeast Asia, Taiwan and China that lives in freshwater as well as in brackish water system as it is one of the euryhaline species. In Malaysia, this fish had attracted the attention of aquaculturist to produce seedling for aquaculture production since in the early of 1980's (Tan and Lam, 1973; Tavarutmaneegul and Lin, 1988; Cheah *et al.*, 1994).

Photo 1.1 Marble goby, *Oxyeleotris marmoratus*

Marble goby has been known to be high value freshwater fish species in few Southeast Asia countries such as Thailand, Singapore, Indonesia (Mohsin *et al.*, 1983; Cheah *et al.*, 1994; Amornsakun *et al.*, 2003; Luong *et al.*, 2005). Marble goby also is one of the popular food fish with high demand in market where the price can reach up to RM49/kg as reported in Department of Fisheries Malaysia (2008). It is also a tasty fish with excellent meat texture and has lucrative market in the Asia region.

1.3 Problem statement

Nowadays, marble goby is one of the economically important freshwater fish with high in demand. However, the demand of this fish is still largely depending on the wild population. This is because of the commercialization of this fish is not widely established. This is due to the constraint in a controlled breeding which lead to the low mass seed production. The inadequate seed supply of marble goby is cause by the high mortality especially during the larval stage (Senoo *et al.*, 2004).

As an approach towards the problem statement above, various abiotic variables or environmental factor can influences the survival and growth of the marble goby larvae. There are salinity, temperature, stocking densities, water quality, photoperiod and light intensity. Among that, light intensity has been shown to be an important ecological factor for fish, where it is said to influence the development from eggs to sexually mature adult (Saunders *et al.*, 1989), which by means it affects all life-stages of fish.

Either intentionally or unintentionally, light intensity can be easily manipulated, through the selection of light source, distance of light source from water surface, depth of the tank and also tank colour (Naas *et al.* 1996). Furthermore, manipulation of light intensity has been shown to influence growth, survival or feeding success of many larval (Britz and Pienaar, 1992). Light intensity helps in affecting of the prey contrast as well as modulates the larval food searching activity (Batty, 1987).

Most of the teleost fish are visual feeder. They were using sight as the main sense to locate the prey. Therefore, sensory organ development especially eyes become an important parameter for the larval feeding performance. In the presence of light, it will helps in improving the success of the foraging activity of the fish. However, excessive bright light may be detrimental to the larval growth and survival (Dey and Damkaer, 1990) as well as unsuitable light condition will give stress response to larvae and affects its development and survival. The problem statement of this study is attributed by understanding the importance of light intensity to enhance larval survival and the absence of in-depth insight information on its requirement to marble goby larvae.

1.4 Hypothesis

Optimal threshold light intensity is crucial for normal larval growth and development. Thus, the hypothesis is rearing larvae under optimum light intensity will improve the growth and survival.

1.5 Objectives

The objective for this study is to determine the effects of light intensity on growth and survival of marble goby larvae as well as determined the optimum light intensity of marble goby larvae. This study has significantly important for the continuous and stable production of marble goby as the larval rearing technique can be improved.

CHAPTER 2

LITERATURE REVIEW

2.1 Marble goby, *Oxyeleotris marmoratus*

Marble goby is mainly distributed in Southeast Asia region such as in Thailand, Cambodia, Vietnam, Singapore, Indonesia, Philippines and Fiji (Inger and Chin, 1962; Mohsin and Ambak, 1983; Cheah *et al.* 1994; Senoo *et al.* 1994a). Marble goby prefer spending most of the time in buried in a habitat that are less disturbance at bottom of quest streams, canals, swamps, or reservoirs that was covered within rocks, woody debris or vegetation area (Lim and Ng, 1990).

Marble goby belongs to the class of Actinoperygii which is ray finned fishes with in order of Perciformes and under family of Eleotridae. The genus name of marble goby is *Oxyeleotris* and species name is *marmorata* or *marmoratus* (Mohsin and Ambak, 1983; Roberts, 1989; Inger and Chin, 2000; Ruzainah, 2008). Marble goby is also under suborder of gobiodei and being considered as huge number under the species classification because consists of more than 2000 species that belongs to the 270 genera (Akihito *et al.* 2000). The taxonomic classification of marble goby is summarized as below:

Table 2.1 Taxonomic classification of marble goby

Class	Actinopterygii (ray finned fish)
Order	Perciformes (perch like fish)
Family	Eleotridae
Genus	*Oxyeleotris*
Species	*marmoratus* or *marmorata*

The maximum body length and body weight of marble goby recorded were approximately 65cm and 2kg (Kottelat, 2001). Kottelat (2001) stated that marble goby has total dorsal spines of 7-7 with 1 anal spine. It also has 8 anal soft rays. Marble goby also have 60-65 predorsal scales without ocellus on caudal peduncle and has black fins with white spots. Besides that, Lim and Ng (1990) also stated that marble goby have two dorsal fins that are symmetrical in pattern. The caudal fin is rounded with separate pelvic fin. The pectoral fin is outstretched and has body torpedo-like shape with snake-like head. In addition, marble goby has pair of small protruding eyes on its head to attack its prey (Kelvin and Peter, 2002).

2.2 Breeding of Marble goby

Marble goby is a multiple spawner and are able to spawn throughout the year under suitable and good condition. The peak spawning activity of marble goby usually occur during May and June (Tavarutmaneegul and Lin, 1988). Through natural or artificial spawning, marble goby can bred either in freshwater or brackish water (Masaya *et al.*, 2006). For artificial seed production, the availability of a good and healthy broodfish is a pre-requisite to the successful breeding. Meanwhile, fish can spawn naturally if in under a good condition.

According to Senoo *et al.* (1994b), broodfish should be reared separately in ponds or tanks for planning of egg collection in seed production. Nowadays, fish breeding programmed are induced by using hormone and become commonly practiced in aquaculture among the farmers. Human Chorionic Gonadotrophin (HCG) hormone has often been used successfully in any fish breeding. Senoo *et al.* (1993) was the first success of induced spawning and technical improvement has been done and achieved since then.

Natural spawning of marble goby can be done either with or without hormone treatment. With hormone treatment, marble goby are successfully spawned. The fertilized eggs usually can be collected from broodfish that range from 155-255g in body weight (Tan and Lam, 1973; Tavarutmaneegul and Lin, 1988; Cheah *et al.*, 1991; Senoo et *al.*, 1994a). Small sized female that range about 100-150g in body weight also can obtained a good quality of eggs (Senoo *et al.*, 1993b).

Under artificial seed production which is stripping method, the sperm are collected by using a sperm collector. When the female is ready to strip out, eggs will be mixed with sperm and fertilized in a bowl (Senoo *et al.*, 1992). Senoo *et al.* (1994c) has successfully produced 1500 eggs with 255g body weight of female using stripping method. However, the male has to be killed in order to obtain the valuable sperm. There are not many studies on the artificial seed production as it needs more handling and high skill and technique for eggs and sperm collection (Senoo *et al.*, 1994a).

2.3 Egg Hatching

The fertilized eggs that attached to the substrate are known as in agrippa shape (Senoo *et al.*, 1994c). According to Senoo *et al.* (1994b), there are not many developmental different in eye pigmentation or yolk sac absorption between unhatched embryos and hatched larvae. High hatching ratio with high survival can be achieved if the eggs hatched during its time (Senoo *et al.*, 1994c). Tan and Lam (1973) also stated that earlier hatched larvae usually are less developed and have low survival than those hatching later. This is because they could not swim and died (Senoo *et al.*, 1994c).

By pushing its tail against the side of egg membrane, the larvae broke free from the eggs during hatching. The tails will pushes through the opening once the suture has been made. Then, by trashing movement of the tails, the larvae freed itself from the egg which was anchored down by its polar threads. Larvae that are unable to free themselves completely from the egg membrane will swam around in the meantime with the egg membrane still covering the head and trunk like massive hood and eventually died within 1-2 hours (Tan and Lam, 1973).

2.4 Larval Development

In newly hatched larvae at 49 hours after fertilization (h AF), the eyes are still not pigmented as well as the mouth and anus were not yet formed. While newly hatched larvae at 2-3 days after fertilization (d AF) will lie on the tank bottom and gradually exhibited the swim-up and sink-down behavior. The newly hatched larvae at 3 d AF already formed the pectoral fins and the mouth was opened. On 4 d AF, the eyes were deeply pigmented and the lower jaw and intestinal tract began to move. During this time, food supply is essential to the larvae as it's indicate the time for first feeding of the larvae (Senoo *et al.*, 1994c).

The inability of the fragile larvae to consume enough live organisms in early stages has caused deformation in juvenile stage with extremely low survival rate. This morphological deformation is due to poor conditions of broodfish or as a result of artificial spawning that would be disadvantageous as it resulted in poor growth and survival (Senoo *et al.*, 1994b). Therefore, food supply is important to increase growth and survival. There are differences in sequential food in early stages. For early larval stage, they usually feed on *Brachionus* sp., Artemia, moina as initial diet.

2.5 Marble goby as Potential Candidate for Aquaculture Programme

Marble goby become one of the best candidates for a systematic aquaculture programme is due to its highly prized and demand of food fish in Malaysia and also in Southeast Asia region. Year 2000 has recorded the production of 277 tons of marble goby by a combination of aquaculture industries of Malaysia, Singapore and Thailand. This quantity has already represented about 74% of the total global aquaculture of gobioid fishes.

The demands of the marble goby are still depending on their natural habitats. This fish are lacking in its biological information except in a few reports that recorded on its culture (Tan and Lam, 1973; Cheah, 1994), rearing condition (Abol *et al.*, 2005), growth and feeding performance that cultured in recirculating aquaculture systems and also effects of the different diets on growth and survival rate at the larval stage (Lim *et al.*, 2000). A study has been conducted in the Truong Dang Cove of Tri An Reservoir, Vietnam that demonstrated the cove culture of marble goby was a prominent prospect ecologically, technologically and also economically (Luong *et al.*, 2005).

2.6 Light Intensity

A widespread consensus exists that the magnitude of recruitment in fishes is determined during the egg and larval period and hence various environmental factors has been studied in respect to their effects on growth and survival (Heath, 1992; Legget and DeBlois, 1994). In the culturing of most teleost fish, the larval rearing is in the primary bottleneck. In order to optimize the success of culturing of the particular species, the specific requirement of the species is needed and important to be determined. Once the basic physical condition in larval environment has been established, they can be incorporated into the design of species-specific larval rearing system and husbandry approaches.

REFERENCES

Abol-Munafi, A.B., Asmanelli, A.M.W.E. and Awang Soh, M. 2005. Effect of exogenous Thyroxine on mophology and development of Thyroid gland in marble goby *Oxyeleotris marmoratus* Bleeker Larvae. *Journal of animal and veterinary advances,* **4**: 624-629.

Akihito, Iwata, A., Kobayashi, T., Ikeo, K., Imanishi, T., Ono, H., Umehara, Y., Hamamatsu, C., Sugiyama, K., Ikeda, Y., Sakamoto, K., Fumihito, A., Ohno, S. and Gojobori, T. (in press). 2000. Evolutionary aspects of gobioid fishes (Teleostei: Perciformes) based on a phylogenetic analysis of mitochondrial cytochrome b genes. *Elesevier* Gene, **259**: 5–15.

Almazán-Rueda, P., Schrama, J.W., Verreth, J.A.J., 2004. Behavioural responses under different feeding methods and light regimes of the African catfish, *Clarias gariepinus* juveniles. *Aquaculture,* **231**: 347–359.

Amornsakun, T., Sriwatana, W. and Chamnanwech, U. 2002. Some aspects in early life stage of sand goby, *Oxyeleotris marmoratus* larvae. *Songklanakarin Journal of Science and Technology,* **24**: 611-619.

Amornsakum, T., Sriwatana, W. and Chamnanwech, U. 2003. The culture of sand goby, *Oxyeleotris marmoratus* I: Feed and feeding scheme of larvae and juveniles. *Songklanakarin Journal Science and Technology,* **25** (3): 367-371.

Barahona-Fernandes, M.H. 1979. Some effects of light intensity and photoperiod on the sea bass larvae *Decentrarchus labrax* L. reared at the Centre Oceanologique de Bretagne. *Aquaculture,* **17**: 311–321.

Barbara, I., Evans and Howard, I, Browman. 2004. Variation in the development of fish retina. *American fisheries society symposium,* **40**: 145-166.

Batty, R. 1987. Effect of light intensity on activity and food-searching of larval herring, *Clupeaharengus*: a laboratory study. *Marine Biology,* **94**: 323-327.

Beaudet, L., H. I. Browman, and C. W. Hawryshyn. 1993. Optic nerve response and retinal structure in rainbow trout of different sizes. *Vision Research,* **33**: 1739–1746.

Besharse JC and Brandon RA: Effects of continuous light and darkness on the eyes of the troglobitic salamander *Typhlotriton spelaeus. J Morphol* **149**: 527, 1976.

Blaxter, J. H. S. 1968. Light intensity, vision, and feeding in young plaice. *J. Exp. Mar. Biol. Ecol* **2**: 293-307.

Blaxter, J.H.S. 1969. Development eggs and larvae. In: Hoar, W.S., Randall, D.J. (Eds.), *Fish Physiology,* vol. 3. Academic Press, New York, pp. 177–252.

Blaxter, J.H.S. 1986. Visual thresholds and spectral sensitivity of flatfish larvae. *J. Exp. Biol*, **51**: 221–230.

Blaxter, J. H. S. and Staines, M. 1970. Pure-Cone Retinae and Retina motor Responses in Larval Teleosts. *J. Mar. Biol. Ass. U.K.*, **50**: 449-460.

Blaxter, J. H. S. 1975. The eyes of larval fish. In: *Vision in Fishes, New Approaches in Research*, ed. M. A. Ali. Plenum Press, New York, 427-443.

Boeuf, G. and Le Bail, P.Y. 1989. Does light have an influence on fish growth? *Aquaculture*, **177**: 129– 152.

Brännäs, E., Alanärä, A. and Magnhagen, C. 2001. The social behavior of fish. In: Keeling, L.J., Gonyou, H.W. (Eds.), *Social Behaviour in Farm Animals*, CABI publishing, New York, pp. 275–304.

Britz, P.J., Pienaar, A.G., 1992. Laboratory experiments on the effects of light and cover on the behaviour and growth of African catfish, *Clarias gariepinus* (Pisces Clariidae). *J. Zool. Lond*, **227**: 43–62.

Chatain B. and N. Ounais-Guschemann. 1991. The relationships between light and larvae of *Sparus aurata*. In: *Larvi'91 - Fish & Crustacean Larviculture Symp.* pp, 310-313.

Cheah, S.H., Senoo, S., Lam, S.Y. and Ang, K.J. 1994. Aquaculture of a high value freshwater fish in Malaysia. The marble or sand goby (*Oxyeleotris marmoratus*, Bleeker). *Naga ICLARM* (International Center For Living Aquatic Resources Management) *Q.17*, **2**: 22-25.

Chesney, E.J. 1989. Estimating the food requirement of striped bass larvae, *Morone saxatilis*. Effects of light, turbidity and turbulence. *Mar. Ecol. Progr. Ser*, **53**: 191– 200.

Clark CW and Levy DA. 1988. Diel vertical migrations by juvenile sockeye salmon and the anti-predation window. *Am Nat*, **131**: 271–290.

Collin, S. P., and H. B. Collin. 1988. The morphology of the retina and lens of the sandlance, *Limnichthys fasciatus*, Creeiidae. *Journal of Experimental Biology*, **47**: 209–218.

Corazza, L. and J. G. Nickum. 1981. Positive photo taxis during initial feeding stages of walleye larvae. *Journal for the International Council for the Exploration of the Sea*, **78**: 492–494.

Craig, J.F. 1977. Seasonal changes in the day and night activity of adult perch, *Perca fluviatilis. L. J. Fish Biol*, **11**: 161–166.

Department of Fisheries Malaysia. 2008. Perangkaan Jabatan Perikanan Malaysia, http://www.dof.gov.my/.

De Silva, S.S., Anderson, T.A., 1994. *Fish Nutrition in Aquaculture*. Chapman & Hall, London. pp 319.

Dey, D. B. and D. M. Damkaer. 1990. Effects of spectral irradiance of the early development of Chinook salmon. *The Progressive Fish-Culturist,* **52**: 141–154

Diaz J.P., Guyot E., Vigier S. and R. Connes. 1997. First event in lipid absorption during post-embryonic development of the anterior intestine in gilthead sea bream. *J. Fish Biol.,* **51** (1): 180-192.

Downing G. Litvak MK. 1999. The effect of photoperiod, tank colour and light intensity on growth of larval haddock. *Aquacult. Int,* **7**: 369-382.

Ellertsen, B., Solemdal, P., Stromme, T., Tilseth, S., Westgard, T., Moksness, E. and Oiestad, V. 1980. Some Biological Aspects of Cod Larvae, *Gadus morhua* L. *Fisk. Dir. Skr. Ser. Hav Unders,* **17**: 29-47.

Fiksen, O., Utne, A.C.W., Aksnes, D.L., Eiane, K., Helvik, J.V. and Sundby, S. 1998. Modelling the influence of light, turbulence and ontogeny on ingestion rates in larval cod and herring. *Fisheries Oceanogr,* **7**: 355–363.

Han D., Xiea S., Lei W., Zhua X. and Yanga Y. 2005. Effect of light intensity on growth, survival and skin color of juvenile Chinese longsnout catfish, *Leiocassis longirostris. Aquaculture,* **248**: 299–306.

Hagedorn, M. M., and R. D. Fernald. 1992. Retinal growth and cell addition during embryogenesis in the teleost, *Haplochromis burtoni. Journal of Comparative Neurology,* **320**: 1–16.

Heath, M. R. 1992. Field investigations of the early life history stages of marine fish. *Advances in Marine Biology,* **28**: 2–174.

Hinshaw, J. M. 1985. Effects of illumination and prey contrast on survival and growth of larval yellow perch, *Perca flavescens. Transactions of the American Fisheries Society,* **114**: 540–545.

Hihelgo, P. T. 2008. *Aquaculture in Ghana, prospects, challenges, antidotes and future prospects.* MSc. Thesis. University of Tromsø Norway.

Helfman, G.S. 1979. Twilight activities of yellow perch, *Perca flavescens. J. Fish. Res. Board Can,* **36**: 173–179.

Helfman, G.S. 1993. Fish behaviour by day, night and twilight. In: Pitcher, T.J. (Ed.), *Behaviour of Teleost Fishes.* Chapman & Hall, London, pp, 366–387.

Hole, G., Pittman, K., 1995. Effects of light and temperature on growth in juvenile halibut, *Hippoglossus hippoglossus* L. In: Pittman, K., Batty, R.S., Verreth, J. (Eds.), *ICES Marine Science Symposia,* Mass Rearing of Juvenile Fish, **201**: 197.

Hunter JR. 1984. Feeding ecology and predation of marine fish larvae. In: Lasker R (ed.) *Marine Fish Larvae Morphology, Ecology and Relation to Fisheries*. Seattle. 253 University of Washington Press. pp **252**: 33-79.

Jentoft, S. and S. Oxnevad. 2006. Effects of tank wall color and up-welling water flow on growth and survival of Eurasian perch larvae, *Perca fluviatilis*. *Journal of the World Aquaculture Society*, **37** (3): 313–317.

Jobling, M. 1994. Fish Bioenergetics. Chapman & Hall, London. pp, 300.

Kawamura, G., Tsuda, R., Kumai, H. and Ohashi, S. 1984. The visual cell morphology of pagrus major and its adaptive changes with shift from palagic to benthic habitats. *Bull. Jap. Soc. Sci. Fish,* **50**: 1975–1980.

Kelvin, K.P.L. and Peter, K.N. 2002. A guide to common freshwater fishes of Singapore. *In* Anonymouspp. 50 The Singapore Science Centre in corroboration with the Raffles museum of biodiversity research.

Kiyono, M. and Hirano, R. 1981. Effects of light on the feeding and growth of black porgy, *Mylio macrocephalus* (Basilewsky), postlarvae and juveniles. **178**: 334–336.

Knights, B. 1985. Energetics and fish farming. In: Tytler, P., Calow, P. (Eds.), Fish Energetics: New Perspectives. Croom Helm Australia Pty. Ltd., Sydney, pp. 309–340.

Kottelat, M. 2001. *Fishes of Laos*. WHT Publications Ltd., Colombo 5, Sri Lanka. pp, 198.

Leggett, W.C. and Deblois, E. 1994. Recruitment in marine fishes. Is it regulated by starvation and predation in the egg and larval stages. *Netherlands Journal of Sea Research*, **32** (2): 119-134.

Liao, C. and Chao, N. H. 1991. Grey Mullet Culture in Taiwan. In: *Handbook of Mariculture: Finfish Aquaculture*, ed. J.P. McVey. CRC Press Inc., Boca Raton, 117-132.

Lim, K.K.P. & Ng, P.K.L. 1990. *The freshwater fishes of Singapore.* Singapore Science Centre press, Singapore. pp, 160.

Luong, V.C., Yi, Y. and Lin, C.K. 2005. Cove culture of marble goby (*Oxyeleotris marmorata* Bleeker) and carps in Tri An reservoir of Vietnam. *Aquaculture,* **244**: 97–107.

Mani-Ponset, L., Guyot, E., Diaz, J.P. and Connes, R. 1996. Utilization of yolk reserves during post-embryonic development in three teleostean species: The sea bream, *Sparus aurata*, the sea bass, *Dicentrarchus labrax* and the pike-perch, *Stizostedion lucioperca*. *Marine Biol*, **126**: 539-547.